Biberach University of Applied Sciences
Institute for Building and Energy Systems

Abridged Report

AUTIFAS

Automation of innovative façade systems with integrated technical building services, taking into account aspects of comfort

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1 Goal of the research project

In modern buildings, integrated façade systems increasingly perform building services functions such as heating, cooling, ventilation, lighting and protection from sun and glare. In this context, decentralized systems offer approaches to address the changed challenges of air conditioning and user perception.

The difficulty of façade and room automation lies in sensibly coordinating the varied, partially counteractive or reciprocal individual functions of different disciplines. In doing so, a reasonable compromise must be made between energetic parameters and parameters that are specific to a certain use (e.g. comfort, manner/extent of the intervention by users).

In current planning practice, these sub-functions are usually planned and implemented separately by different participants in the planning process (façade planners, ventilation system planners, electrical system planners, heating planners, instrumentation planners) and are therefore generally only sub-optimally coordinated. This also leads to recurring technical and organizational problems with interfaces over the course of the design and implementation process of a building project.

Unlike in conventional building automation, there are currently no standardized automation functions and concepts yet. Thus, one important goal of this research project is the development of a modular library of standardized automation functions and, based on this, the design of integrated automation strategies using individual functions (e.g. coordination of sun/glare protection, use of daylight, adjustment of artificial lighting, as well as natural and mechanical ventilation). In the process, in addition to need-based and user-friendly design, requirements regarding energy efficiency and perceived comfort should be taken into account through dependencies and reciprocal relationships of the functions. Here, integrated façade systems should be viewed as maximally self-sufficient sub-systems and integrated into the room automation and higher-level building automation appropriately.

In addition to this, modeling approaches that are as simple as possible are analyzed in this project as a basis for designing higher-level automation strategies, using a façade test stand at Biberach University of Applied Sciences with a specific façade system as an example. It will then be examined, to what extent these results can be transferred to façade automation in general and where there are approaches for the targeted advancement of simulation models through the integration of façade system models.

2 Implementation of the research task

A key emphasis of the implementation of the research project was the development of a modular automation library for façade automation, based on the existing guidelines for room and building automation according to the VDI guidelines VDI 3813[1] and VDI 3814[2].

For this, sensor, actuator and application functions were defined with regard to the façade automation based on the room automation functions according to VDI 3813-2. The representation of function blocks in a standard-compliant programming language makes it possible to use them in different environments. In addition to this, the input data, output data and parameters are presented in a table with comments. Figure 2.1 shows an example of a function block in the representation according to VDI 3813-2 and Table 2.1 shows an excerpt of the assignment of functions according to VDI 3813-2 with the “Autifas library” of functions for façade automation that was developed in this project.

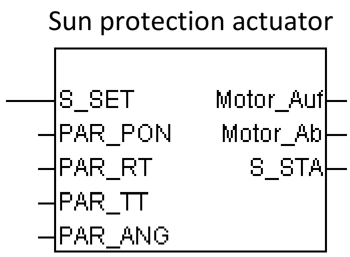

Figure 2.1: Automation function of sun protection actuator

Table 2.1: Mapping of façade automation functions to automation functions according to VDI 3813-2

VDI 3813-2	Autifas library	Hardware
Functions according to the outline of the guideline VDI 3813 Blatt 2		
6.2.3 Sun protection actuator	2.3 Sun protection actuator	
	2.3.1 Sun protection actuator with digital output	

Aspects of energy efficiency and comfort are key criteria of the system’s design, along with usage parameters contingent on the time of day, weather, solar radiation and type of use. Energy efficiency is taken into account according to the BACS efficiency classes outlined in DIN EN 15232[3] by categorizing functions from room and building automation according to the functional requirements.

[1] VDI 3813: Building automation and control systems (BACS) – Blatt 1: Fundamentals for room control, Blatt 2: Room control functions (RA functions); Berlin; Beuth Verlag; May 2007 and May 2011

[2] VDI 3814: Building automation and control systems (BACS) – Blatt 1: System basics; Berlin; Beuth Verlag; November 2011

[3] DIN EN 15232: Energy performance of buildings - Impact of Building Automation, Controls and Building Management; German version; Berlin; Beuth Verlag; September 2012

To implement the automation, an appropriate equipment with sensors (e.g. for temperature / humidity / air quality) and actuators (e.g. dimming actuator, blind actuator, outlets for heating / cooling) is necessary. In the scope of the research task, the feasibility of the methodological approach was tested and implemented based on the analysis of the results.
In addition to this, a general planning methodology was developed in order to make a systematic and standardized planning process for integrated façade systems possible. Unambiguous definitions allow for a clear and effective approach, along with a reduction in misunderstandings. The planning phases start with definitions for all the involved disciplines of functions in the user-requirement specification, which are described in the functional specification using formal descriptions and displayed in a flow chart, as well as in more detail in the next phase, in the form of automation diagrams and lists of functions. Finally, the implementation takes place, with the conversion of the plans into function blocks and macro functions according to the programming languages outlined in IEC 61131[4].

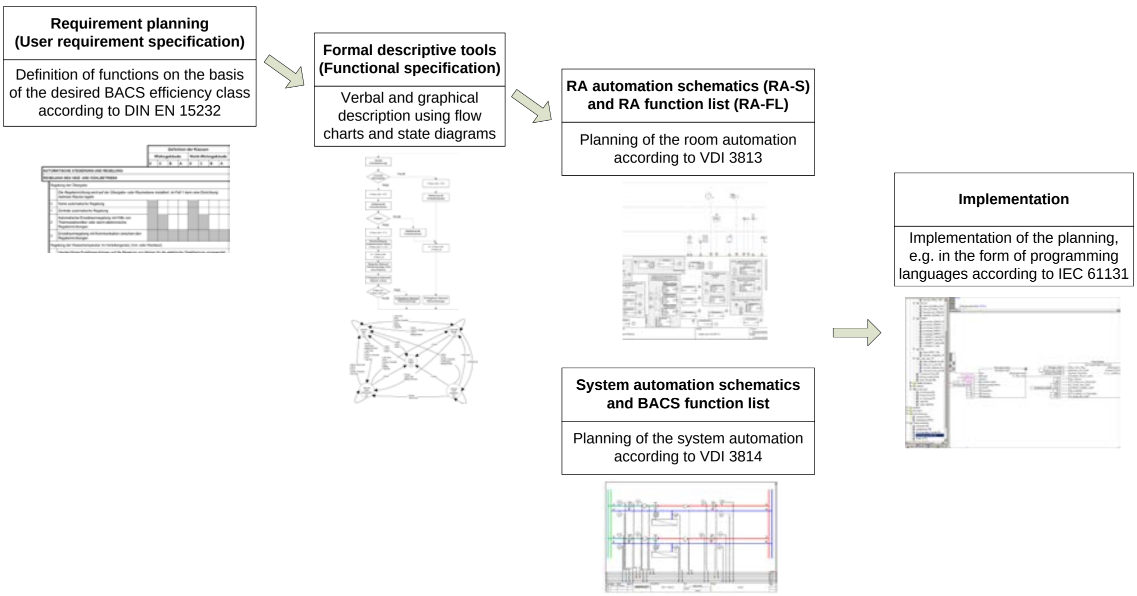

Figure 2.2: Overview of the general planning methodology in different planning phases

The concrete application and testing of the developed automation library took place at the façade test stand of Biberach University of Applied Sciences. It consists of a test room supplied with heating and refrigeration for adjusting the temperature of the enclosing surfaces, an air/air heat exchanger and a façade element produced by the company Wicona, see Figure 2.3.

[4] IEC 61131: Programmable Controllers: Berlin; Beuth Verlag; December 2009

Figure 2.3: Test façade with test room and hydraulic systems

The façade element has double-glazed windows, with a layer of single glazing in front of them. Sun and glare protection are located between the two layers, along with the lighting. Additionally, a decentralized ventilation unit is integrated along the entire depth of the façade, using ventilation flaps to allow natural air flow in addition to mechanical ventilation, as well as a combination of the two (hybrid ventilation).

The entire automation of the façade, the room and the hydraulic systems as well as the recording of scientific test results takes place via a higher-level automation station (AS). The hardware structure of the automation can be differentiated into three levels:

a) The field level comprises all sensors and actuators, which exchange information using analog signals or bus communication.
b) The automation level contains the automation station as well as two secondary units for the differentiated collection and processing of data.
c) The management level role is to visualize measurements, enable remote monitoring and provide higher-level access to the open-loop and closed-loop control of the field and automation levels.

Figure 2.4 shows an overview of the implemented automation system for the façade test stand.

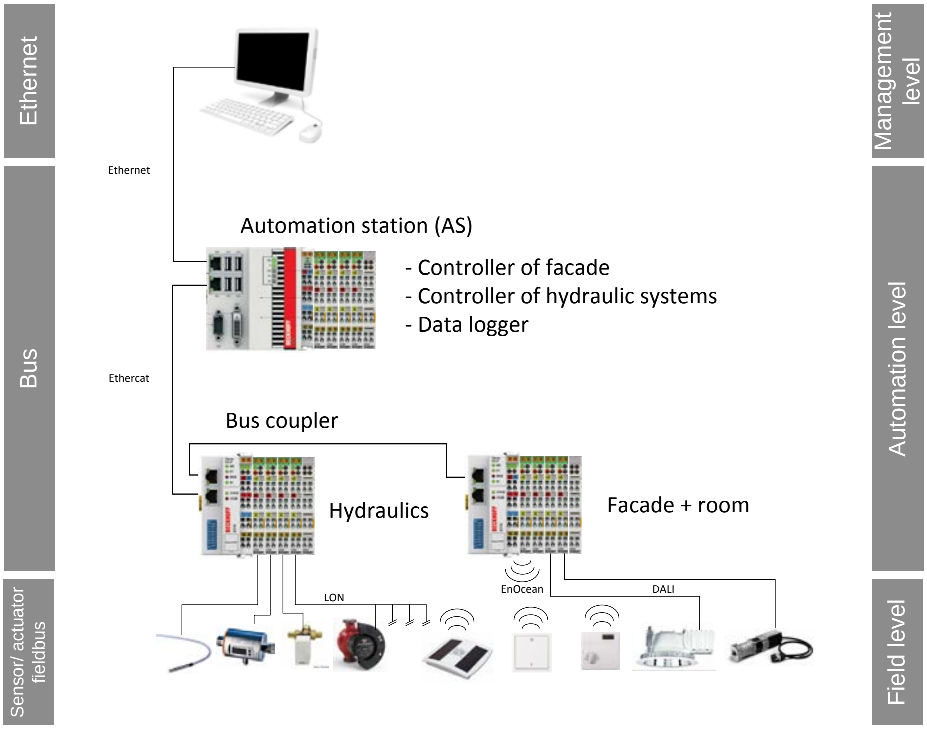

Figure 2.4: Automation engineering concept of the test façade including the test room

Flow charts, as a formal descriptive tool, provide the basis for programming the automation, graphically documenting the configuration of the process, along with automation diagrams and function lists according to VDI 3813 and VDI 3814, which map the relationship of the individual functions and macro functions to each other.

In the experimental tests with the model façade element, the identification of system parameters and characteristic curves for putting the open-loop and closed-loop controls of the façade test stand into operation play a major part. Opportunities to gather data are provided by experimental testing of the actual systems using metrology as well as through a selective consideration of individual factors in simulation analyses.

Within the scope of the research project, flow rate and heat exchanger of the ventilation unit, the influx of supply air and the air-flow in the room as well as sun and glare protection, taking illumination and solar radiation into account, were examined in more detail.

The basic approach of a superior closed-loop control was pursued with an optimized target-value specification of temperature and the flow rate of the supply air, taking into account energy efficiency and aspects of comfort. Parameters of the “decision-making criteria”, “ventilation type” and “energy level” modules have some influence on the higher-level closed-loop control and influence the dimensioning of the target value directly.

In this context, the decision-making criteria module refers to aspects of energy efficiency as well as thermal and hygienic comfort. At the same time, it must be taken into account that the individual criteria are reciprocal and must be considered together.

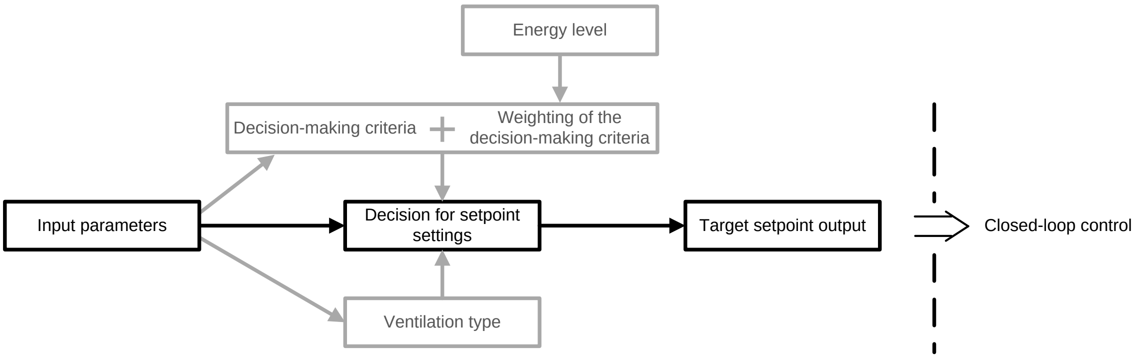

Figure 2.5: Modular structure of the higher-level closed-loop control, taking into account the criteria energy efficiency and comfort

The closed-loop control is also based on the differentiation between the energy levels according to their usage requirements, into economy, precomfort and comfort according to the guideline VDI 3813-2. The decision-making process for the selection of the energy level is depicted in a flow chart, taking into account the parameters time, presence and individual influence. Apart from the specified target value for the room temperature, the output values also include the weighting of the individual criteria, thus assigning energy efficiency and comfort their respective importance. This means that if people are present, the goal of energy-efficient closed-loop control is de-prioritized in favor of the perceived comfort.

The differentiation of the ventilation types into natural and mechanical ventilation as well as a combined hybrid ventilation offers a selection that is dependent on the desired ventilation function and the current thermal parameters.

The examination of higher-level open- and closed-loop controlling strategies is part of the effort of optimizing the use and coordination of different building services systems on the basis of comfort and energy efficiency. At the same time, contradictory effects due to existing reciprocities between the decision-making criteria as well as different intensities of perception on the part of the users must be taken into account. For the weighting of the criteria, this means that the actual proportions are to be calculated optimally depending on the specific situation. Using ambient air for ventilation when ambient air temperatures are extreme can result in a high hygienic comfort and, at the same time, lead to a reduction in energy efficiency and thermal comfort.

In particular when it comes to hygienic comfort, it must be taken into account that the user does not have a reliable perception of the indoor air quality due to adaption and thus requires a metrological assessment of the climate.
The key statement of the weighting distribution lies in the differentiation of the situation and the associated prioritization of individual decision-making criteria. In the scope of the research project, only a differentiation between energy efficiency and comfort takes place, without additionally differentiating between experienced thermal and hygienic comfort. Essentially, the economy level has no requirements in terms of comfort or user acceptance, since no user presence is assumed during this time period. At the precomfort level, the importance of comfort increases, to prepare the room for a possible occupancy. With regard to hygienic comfort, the required air quality should be ensured at this time so that entering users do not experience any inconvenience. The comfort level differentiates between weighting specifications and user interaction.

While the limits of individual interventions are selected in such a way that comfort is always given the higher priority.

3 Summary of the most important results

The primary result of this research project is an open, modular automation library for façade automation that has been designed, tested and documented using the example of the analyzed façade element at Biberach University of Applied Sciences for the functions heating, ventilation and lighting. The already familiar closed-loop control strategies and library modules for room automation according to VDI 3813-2 served as a basis for the development of the modular library for façade automation. The implementation took place according to the energy efficiency classes according to DIN EN 15232, the representation of functions according to VDI 3813/ 3814 and the programming languages according to IEC 61131.
Based on these standards and guidelines, a standardized planning methodology can be applied that allows a structured and systematic approach to the planning process and the subsequent implementation. Due to this methodology, the functions, especially the macro functions of the guideline VDI 3813-2 are applied. Since problems with individually developed code are very frequent in practice, using these clearly defined functions represents a particular quality with regard to the use of standardized functions. In the scope of the project, a modular automation library for this purpose was developed based on these functions, which can be easily expanded at any time.

For the concrete implementation at the façade test stand at Biberach University of Applied Sciences, the limits of this methodology also became apparent, since to some extent a consistent application of standardized functions could not be readily implemented at the façade test stand. One reason, for example, lay in the practical constraints of using a façade test stand, e.g. in terms of the hardware used for the air-conditioning unit, but also in the selection of the specific hardware for the automation solution. As a result, some hardware-specific adaptations were necessary which will also always be necessary in practice.

In using defined macro functions, it became apparent that the programmer has an increased initial training effort with this system, since the methodology and approach on the basis of VDI 3813 must first be understood. However, as soon as this initial training has taken place, the programmer can implement a solution more systematically and effectively. In particular when a programmer must deal with existing systems, e.g. for optimizations, time can be saved, since initial training for existing customized programming is not necessary.

For the research on the formulation of improved closed-loop control strategies, a number of simulation studies were performed in addition to the experimental investigations at the façade test stand. The methods used here included CFD flow simulations to study the supply-air flow as it enters and the flow of air in the room. In addition to this, thermal room simulations were used to develop and test closed-loop control concepts.
The analysis of models of characteristic maps and characteristic curves showed that quantitative relationships of components and sub-systems can be modeled well and can, in principle, be used to facilitate closed-loop controlling if there is no measuring

equipment. However, it must be taken into account that models of characteristic maps and characteristic curves are limited to concrete system constructions in the representation of information and, as a rule, cannot fully reproduce the dependencies of factors influencing the general interrelationships of any construction.
For instance, applied to the ventilation control, this means that with a valve controller and corresponding sensors (e.g. CO_2 sensor), closed-loop control strategies can be implemented for a controlled natural ventilation – and also combined with mechanical ventilation for a hybrid ventilation. If there are no sensors, the measured data can be replaced by providing the corresponding characteristic curves of the ventilation process. In both cases, the higher-level room automation must first make a decision regarding the operating mode that will be used, between natural, mechanical or hybrid ventilation, taking into account energy efficiency and aspects of comfort.

With the experimental and theoretical tests that were performed in this project, valuable fundamental insight can be gained with regard to the possibilities, but also the limitations of higher-level closed-loop control strategies in the context of energy efficiency, ease of use and aspects of comfort. However, there is still a considerable need for research and development in this matter for follow-up projects to continue the research, in order to reach more substantiated, in-depth and, above all, more general conclusions.